Thermal Dependence of the Metsähovi Levelling Test Field

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Key words: Precise levelling, bench mark, temperature of bedrock, deformation of bedrock

SUMMARY

Observations at the Metsähovi levelling test field have been carried out since autumn 2000, earlier yearly in spring and autumn, later since 2003 every month. The test field consists of 21 bench marks, of which 16 have been fastened in bedrock. The vertical movements of 14 bedrock bench marks have been small but two successive bench marks move even three millimetres compared to the others. There exists a strong correlation between the bedrock temperature and the movements of these two bench marks.

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1. INTRODUCTION

The reliability of the bench marks plays an important role in high precision surveying. Whenever it is possible they are fastened in bedrock.
Väisälä (1967) reported horizontal movements of bolts in bedrock at the Tuorla observatory. The stability of the levelling bench marks fastened in bedrock in the Finnish precise levellings has been investigated by Lehmuskoski (1996).
Since autumn 2000 repeated levellings have been carried out at the Metsähovi levelling test field. Unexpected movements due to temperature variations were found. This paper gives the results of the measurements since July 16, 2003, when the temperature measurements of bedrock were started.

2. METSÄHOVI LEVELLING TEST FIELD

The Metsähovi levelling test field (Figure 1) is located in Southern Finland near the Metsähovi Space Geodetic Station. Its coordinates are 24.4°E and 60.2°N. The test field was established in autumn 2000 for studying the accuracy of levelling instruments (Takalo et al., 2001). The bench marks are fastened in bedrock. There are also some auxiliary bolts fastened in boulders or supports but these are not reviewed here. The levelling route is a gravel road. The total length of the test field is 0.98 kilometres.
The previous studies have revealed that the most moving bench mark is M52. In order to focus the studies better, four new bench marks, M511, M512, M521 and M522, were established at its neighbourhood in summer 2003. Also, to observe the bedrock temperature, a 40 cm deep borehole was drilled close to the bench marks M52 and M2.

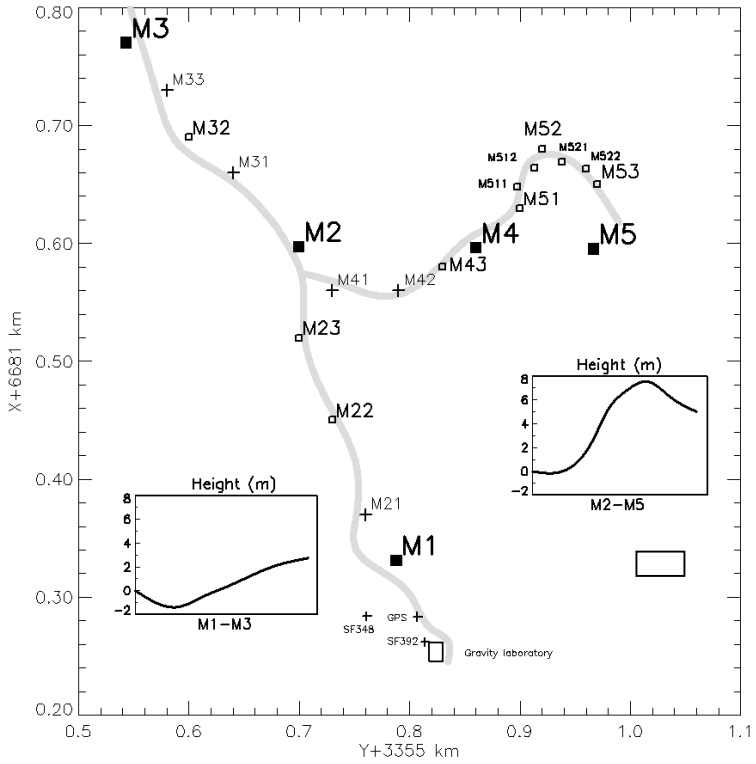

Figure 1. The Metsähovi levelling test field. ■ = bench mark in bedrock, □ = lock bolt bench mark in bedrock, + = auxiliary bench mark in boulder or support. The coordinates are in the Finnish KKJ-system.

The structure of the bedrock in the area was scanned in April 2003 using a Ramac Ground Penetrating Radar with 500 Mhz frequency (Figure 2). The surface of the bedrock near M52 looks widely unbroken but the radar picture reveals that there are fractures under the surface (Figure 3).

Figure 2. Ramac Ground Penetrating Radar in use

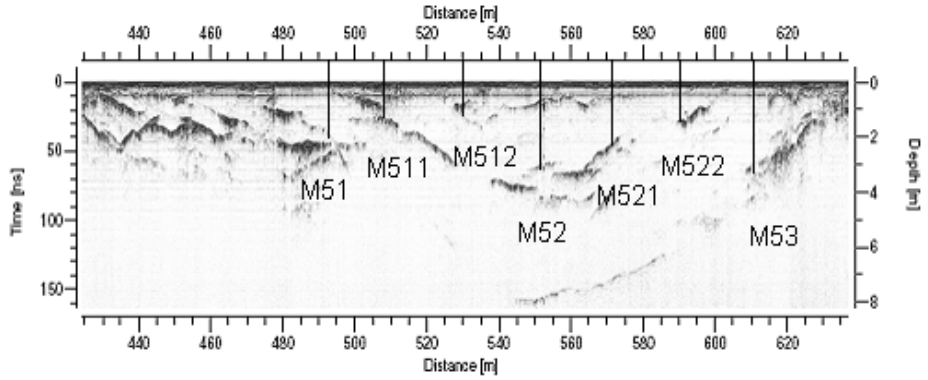

Figure 3. Structure of the bedrock near bench mark M52. The picture has been created using the Ground Vision program.

3. MEASUREMENTS, REDUCTIONS AND RESULTS

The levelling method, the equipment and the corrections for the rod readings were the same as in the Third Levelling of Finland. The digital levelling system Zeiss DiNi12 with 3 m Nedo bar code invar rods was in use. The air temperatures 2.5 m and 0.5 m above the ground were measured with a Fluke 54 II thermometer. During the levellings the distances from the instrument to the rods were equal with an accuracy of some decimetres.

The following corrections for the rod readings were taken into account: refraction correction with the Kukkamäki formula (Hytönen, 1967), rod correction (Takalo, 1985), tidal correction (Heikkinen, 1978) and zero point correction for the rod pairs. The rod calibrations and the determination of the zero point corrections were carried out in spring and in autumn using the FGI rod comparator (Takalo, 1999), (Takalo and Rouhiainen, 2002).
Some observations are missing due to the woodpiles over some bench marks during the levellings (Table 1).

Table 1. Levelling results and bedrock temperatures. Observations have been carried out in 2003, except 13.1. and 13.2., in 2004. Column 1=bench mark interval, column 2=distance between bench marks, column 3=height difference at 16.7.2003 (mm), columns 4-14=change of height difference compared to column 3 (mm).

Date	**Dist**	**16.7.**	**5.8.**	**14.8.**	**29.8.**	**16.9.**	**30.9.**	**23.10**	**6.11.**	**28.11**	**11.12**	**13.1.**	**13.2.**
Temp. (°C)	**(m)**	**23.7**	**23.1**	**20.0**	**15.8**	**13.5**	**10.0**	**-1.2**	**6.0**	**2.4**	**0.6**	**-1.8**	**-0.8**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
M1-M22	133	-1360.51	0.00				-0.19						
M22-M23	73	808.40	0.07				0.16						
M23-M2	76	875.43	-				-						

Date	Dist	16.7.	5.8.	14.8.	29.8.	16.9.	30.9.	23.10	6.11.	28.11	11.12	13.1.	13.2.
Temp. (°C)	(m)	23.7	23.1	20.0	15.8	13.5	10.0	-1.2	6.0	2.4	0.6	-1.8	-0.8
1	2	3	4	5	6	7	8	9	10	11	12	13	14
			0.50				0.17						
M2-M32	140	1692.11	-0.31				-0.10						
M32-M3	108	724.36	0.08				-0.16						
M2-M43	172	2939.78	-0.12				0.01						
M43-M4	33	1917.07	0.08				0.01						
M4-M51	54	1875.66	0.17	0.18	0.04	-0.13	0.01	-0.31	-0.36	-0.48	-0.39	-0.19	-0.16
M51-M511	18	-47.74	-0.22	-0.15	-0.07	0.06	0.10						
M511-M512	25	429.53	-0.01	-0.07	-0.15	-0.24	-0.11						
M51-M512	38	381.78	-0.23	–0.22	-0.22	-0.18	-0.01		0.19	0.30	0.35	0.35	0.39
M512-M52	22	416.71	-0.06	-0.80	-1.45	-1.78	-2.25		-2.65	-2.82	-3.04	-3.26	-3.28
M51-M52	60	798.50	-0.28	-1.02	-1.68	-1.69	-2.26	-2.70	-2.45	-2.52	-2.69	-2.90	-2.89
M52-M521	22	-279.20	0.13	0.36	0.58	0.67	0.75	0.64	0.61	0.54	0.54	0.62	0.63
M521-M522	21	-355.42	-0.10	0.40	0.92	1.23	1.54						
M522-M53	21	-603.61	-0.08	-0.03	-0.01	-0.03	0.05						
M521-M53	41	-959.04	-0.18	0.38	0.91	1.20	1.60	2.44	2.25	2.49	2.69	2.81	2.83
M52-M53	61	-1238.23	-0.05	0.74	1.50	1.87	2.35	3.08	2.86	3.04	3.24	3.44	3.46
M53-M5	76	-1299.50	0.24	0.13	0.13	0.13	-0.11	-0.25	-0.45	-0.58	-0.64	-0.77	-0.94
M4-M5	251	136.42	0.07	0.03	-0.01	-0.09	-0.00	-0.18	-0.40	-0.56	-0.48	-0.43	-0.52

The previous levellings in 2000-2002 (Lehmuskoski et al., 2003) indicated that the vertical movement of M52 in proportion to M2 was about 2 mm and that of the other bench marks stayed within 0.5 mm. One of the new bench marks established in spring 2003, M521, has moved alike M52 as a function of the bedrock temperature (Table 1, Figures 4, 5 and 6). Their maximum vertical movement has been even about 3 mm compared to the neighbouring bench marks. Thus their change of the elevation is 0.12 mm/°C.

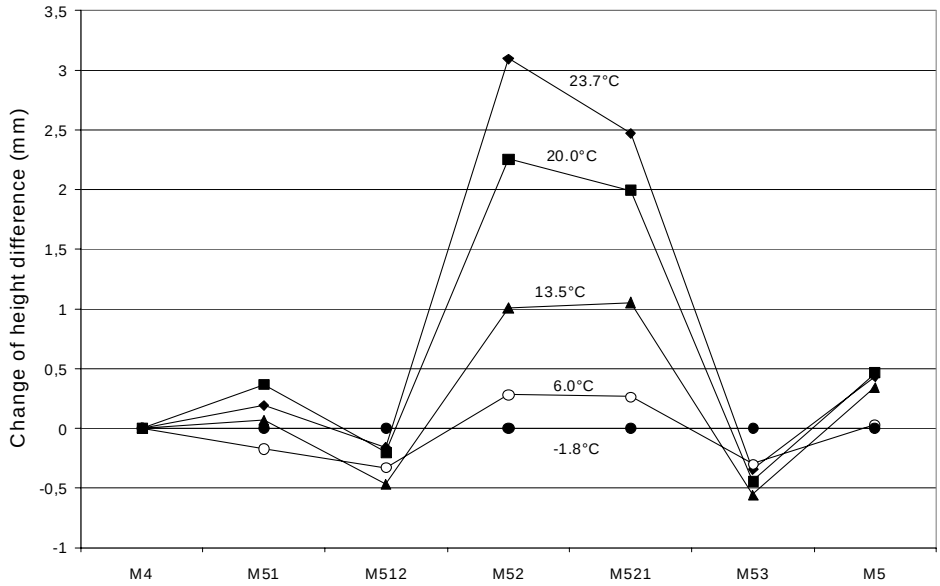

Figure 4. Changes of the height differences of the interval M4-M5 as a function of the bedrock temperature

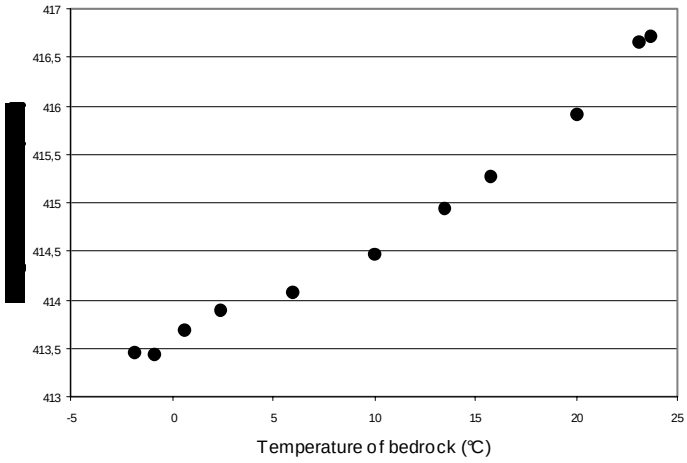

Figure 5. Height difference of the interval M512-M52 as a function of the bedrock temperature

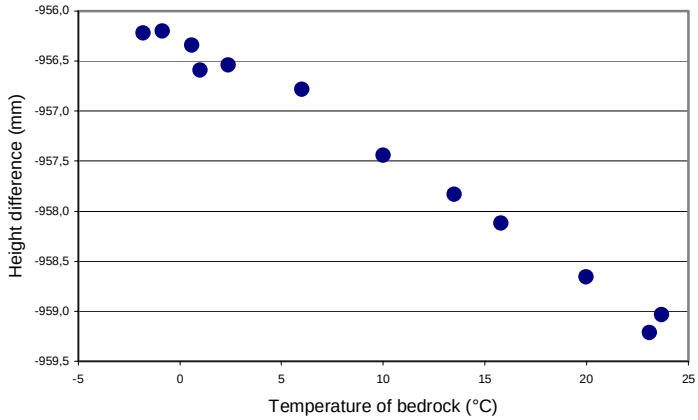

Figure 6. Height difference of the interval M521-M53 as a function of the bedrock temperature

4. CONCLUSIONS AND FUTURE ACTIONS

The Metsähovi test field has been used for testing levelling instruments. Its useability for that purpose is still good, when the interval M4-M5 has been investigated. This interval has a geodynamical interest, too.

There are two bench marks, M52 and M521, whose elevation changes a few millimetres as a function of the bedrock temperature. The vertical component of the thermal expansion of the bedrock can not explain the effect. To understand better the mechanism of the bedrock deformation also the horizontal movements of the bench marks will be monitored with the vertical control.

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REFERENCES

Heikkinen, M., 1978. On the Tide-Generating Forces. *Publ. Finn. Geod. Inst. 85*. Helsinki.

Hytönen, E., 1967. Measuring of the Refraction in the Second Levelling of Finland. *Publ. Finn. Geod. Inst. 63.* Helsinki.

Kakkuri, J., 1980. Vertical movement of levelling bench marks in Finland. *Proceedings of the Second International Symposium on Problems Related to the Redefinition of North American Vertical Geodetic Networks. 579-586.* Ottawa, Canada.

Kukkamäki, T.J. and P. Lehmuskoski, 1984. Influence of the Earth Magnetic Field on Zeiss Ni002 Levels. *Rep. Finn. Geod. Inst. 84:1.* Helsinki.

Lehmuskoski, P. (1996). Active fault line search in Southern and Central Finland with precise levellings. *Rep. Finn. Geod. Inst. 96:5*. Kirkkonummi.

Lehmuskoski, P., P. Rouhiainen, V. Saaranen and M. Takalo, 2003. On stability of the Metshovi test field for levelling instruments. *NKG Working group for Height Determination,* Copenhagen, April 1. 2003.

Lehmuskoski, P., P. Rouhiainen, V. Saaranen, M. Takalo ja H. Virtanen, 2003. Metsähovin vaaitustestikentän ensimmäiset kaksi vuotta -liikkuvatko kalliokiintopisteet? *Maanmittaus, Vol.78, N:o 1-2, 2003.* Helsinki.

Takalo, M., 1985. Horizontal-Vertical Laser Rod Comparator. *Rep. Finn. Geod. Inst. 85:2.* Helsinki.

Takalo, M., 1999. Verification of Automated Calibration of Precise Levelling Rods in Finland. *Rep. Finn. Geod. Inst. 99:7.* Kirkkonummi.

Takalo, M., P. Rouhiainen, P. Lehmuskoski and V. Saaranen, 2001. On calibration of Zeiss DiNi12. *FIG Working Week 2001, May 6-11, Seoul, Korea*. Proceedings.

Takalo, M. and P. Rouhiainen, 2002. On System Calibration of Digital Levels. *Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen and H. Suurmäki) :278-283.*

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